ENGINEERING EXPERIMENT STATION
of the Georgia Institute of Technology
Atlanta, Georgia

FINAL TECHNICAL REPORT

PROJECT NO. A-241-3

GROUND PLANE SURVEY

By

WILLIAM B. WRIGLEY

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DEPARTMENT OF THE NAVY
OFFICE OF NAVAL RESEARCH
CONTRACT NO. NOnr-991(02)
SUB-TASK NO. 3

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30 June 1956

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1. Objective

The objectives of this survey were to investigate the state of the art of antenna ground-plane construction and utilization, to prepare specifications for suitable facilities for antenna research at Georgia Tech, and to supervise construction of such facilities. Detailed design and construction costs will be borne by the Georgia Tech Engineering Experiment Station.

2. Literature

A literature search disclosed relatively little significant information with the exception of two papers[1,2] concerning the effects of edge reflections on impedance measurements. These effects are gradually reduced with a circular ground plane as the diameter or the scaling frequency is increased. However, these effects are considerably reduced with a square ground plane, presumably due to the partial phase cancellation of reflected waves with various propagation distances from the antenna terminal to the edge of the plane.

3. Facilities Visited

Two ground plane facilities were visited, each illustrating radically different requirements and construction techniques. The U.S. Navy Electronics Laboratory at San Diego, California has a ship model antenna range which is over 100 ft in diameter, and is constructed on the ground, integral with a paved surface. A detailed description of this facility is contained in NEL

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[1] Meier, A. S. and Summers, W. P., "Measured Impedance of Vertical Antennas Over Finite Ground Planes," Proc. I.R.E., 37, (June 1949) 609-616.

[2] Storer, J. E., The Impedance of an Antenna over a Large Circular Screen, Technical Report No. 119, Cruft Laboratory, Harvard University, 1950.

classified Report No. 384. Pertinent construction details quoted from a letter by Mr. V. C. Smith, Head of the Ship Antenna Systems Section at NEL are as follows:

"Two types of construction have been employed for antenna ground planes at NEL. Where heavy vehicle traffic is anticipated, the ground plane consists of wire mesh. Hardware cloth, galvanized after weaving, is stretched over asphalt concrete paving. While under tension the hardware cloth is spiked to the asphalt concrete. Hog-nose rings and pliers are then used to bond adjacent strips of hardware cloth at intervals of about three to six inches. Finally, each ring is soldered to insure contact and the resulting joint bathed with a neutralizing solution of soda and water to prevent corrosion by the acid flux. The cost of this method of construction depends considerably upon the weight of the hardware cloth used. For 1/2" mesh the material cost is about $0.10 per sq. ft. and labor for installation about $0.30 per sq. ft.

"Another method for providing a ground plane where heavy vehicle traffic is not anticipated employs metal spraying. Advantages of this technique are: (1) a smooth continuous surface is obtained; and (2) the edge of the ground plane can be scalloped or spikedshape to reduce or eliminate reflections. In this method a smooth concrete paving is first installed. Lead is then sprayed over this surface with a metallizing gun to form the conducting ground plane. Usually the lead is sprayed to a thickness of 0.007 to 0.010 inches to provide both a satisfactory electrical and mechanical surface. New types of metallizing guns spray at least 100 pounds of lead wire per hour and are at least 60% efficient. Approximately 1/3 pound of lead wire, costing $0.08 to $0.10 per pound, is required to spray each square foot. Labor cost will of course depend upon the availability of a metallizing gun, but should not exceed the cost of laying hardware cloth."

The Cruft Laboratory at Harvard University in Cambridge, Massachusetts has had experience with several vertical and horizontal instrumented ground planes. Researchers there now believe there is some question as to the universal value of large vertical planes constructed on the side of a building in that reflections from the natural ground may disturb scattering measurements.

Their latest facility (about two years old) is a 48-ft x 24-ft solid aluminum horizontal plane erected on top of the Gordon McKay Laboratory of Applied Science. The roof of this building was originally designed to accommodate this installation. Dr. Ronald Row has used this plane for precision scattering measurements at 792 mc (38 cm) with negligible edge reflection effects when measurements are made at least six wavelengths inside the edge.

The plane is made up of 4-ft x 8-ft x 1/8-in. aluminum sheets. A framework of 2-1/2 in. aluminum channel supports the flat sheets and the channel is in turn supported by 5-in. aluminum I beams every 8 ft. The I beams are supported by 1-1/2-in. studs with adjustable leveling nuts. Four removable panels, each 4 x 4 ft, are located in the center of the plane over the hole in the roof. Each of these panels has a 10-in. removable circular plate at its center.

The entire structure was prefabricated by a local contractor and cost less than $6000, including two man-months for final assembly. The only unexpected difficulty was that the 1/8-in. aluminum sheets were not square when delivered and had to be run through a large milling machine.

Dr. Row made several recommendations and comments:

a. All-aluminum construction is strongly recommended because of thermal expansion. Harvard has experienced intolerable distortions and separations with other planes built with a wooden framework and a screened surface surrounding a solid center-section. Aluminum oxide accumulates on the recommended surface, however, causing guided or surface waves which may distort antenna pattern measurements.

b. Use metal plates with square corners to form the plane surface in order to prevent excessively wide cracks between adjacent sheets at the joints.

c. Do not allow the separation between adjacent plates to exceed 1/2 of a wavelength of the shortest wave to be used in tests. (Metal-to-metal contact between adjacent plates is not critical since contact can be obtained through the "backing" angle or beam under the joint.) If desired, cracks can be filled with putty and painted with silver paint and aluminum foil applied over joints while paint is wet; this eliminates all cracks.

d. If the outer edges of the plane are sloped down gradually (somewhat like an air foil section), the electrical characteristics of the plane might possibly be improved over the characteristics of a plane without sloped edges.

e. Provide easy access from instrument room (which might be a screen room underneath the center of the plane) to the top surface of the ground plane.

f. Provide removable panels (about 4 sq ft in size) with removable circular sections (about 2 ft in diameter) in their centers; four of these removable panels should be located near the center of the plane, and one or two should be located near the outer edges of the plane. The circular sections should be constructed so that they can easily be rotated manually (and possibly motor driven).

4. The Georgia Tech Ground Plane

While the NEL type plane would be ideal for unscaled hf measurements, no suitable area is available on the Georgia Tech campus for such a large installation. A horizontal roof type ground plane could be constructed on the Research Building or on any of several buildings in the immediate vicinity, the Research Building being the most convenient for those personnel who have an immediate need for this facility.

Two possible approaches have been considered for constructing a Cruft Laboratory type ground plane on the Georgia Tech Research Building. The first involves a combination ground plane and microwave range receiving terminus located at position A(existing microwave facility) in Figure 1. A sketch of this proposed combination facility is shown in Figure 2. The support columns are necessary to elevate the structure high enough to avoid reflections from the adjacent shop area wall. The porch would accommodate the present microwave terminus equipment, and the instrument room would be common to both activities.

It appeared initially that much was to be gained through a combination facility, particularly in that considerable instrumentation could be shared between the two activities. Furthermore there is an inherent financial saving in any such combination structure as compared to the cost of constructing and maintaining two separate facilities. There is some question, however, as to

Figure 1. Georgia Tech Research Building.

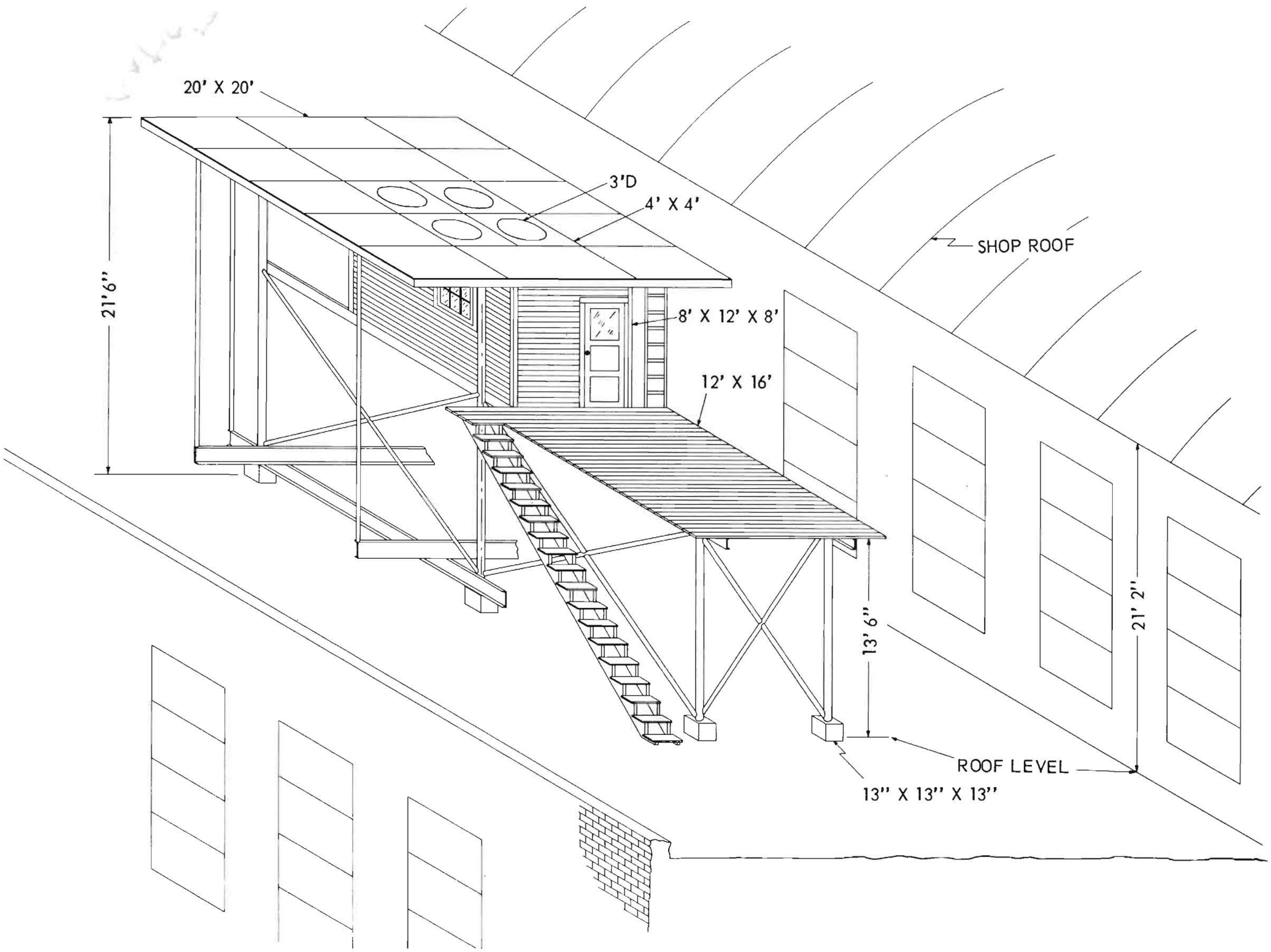

Figure 2. Proposed Combination Ground Plane-Microwave Range Facility.

mutual interference between the two activities during periods of joint usuage. This is of particular concern with microwave antenna measurements of nulls and minor lobes.

An alternative to the above combination facility is to erect a ground plane at the location shown in Figure 3 (to the left of the area visible in Figure 1). It is believed that, from a long range point of view, this approach will result in more efficient operation of all antenna research and development activities. This alternative has been selected and, as can be seen in Figure 3, the Georgia Tech Antenna Ground Plane Facility is presently under construction.

The structure will be similar to that shown in Figure 2 except that the porch and elevating columns will not be required. Also, the plane area will be 20 x 24 ft instead of 20 x 20 ft as planned for the combination facility. This area should be adequate for frequencies down to 300 megacycles. Meier and Summers[1] indicated only trivial impedance errors for square ground planes six wavelengths on a side.

The construction details of the plane are essentially similar to those of the Cruft Laboratory facility with the exception that steel instead of aluminum members will support the aluminum sheets. The aluminum plates are secured to each other along all joints to form an integrated plane. This aluminum plane will be secured to the steel beams with sliding type clamps which will allow for unequal thermal expansion of the two materials.

Provisions will also be made for measuring antenna patterns. A 12-ft boom, not shown in Figure 2, will be pivoted near the middle of one long edge of the plane. This boom will permit a probe dipole to be swung in a vertical

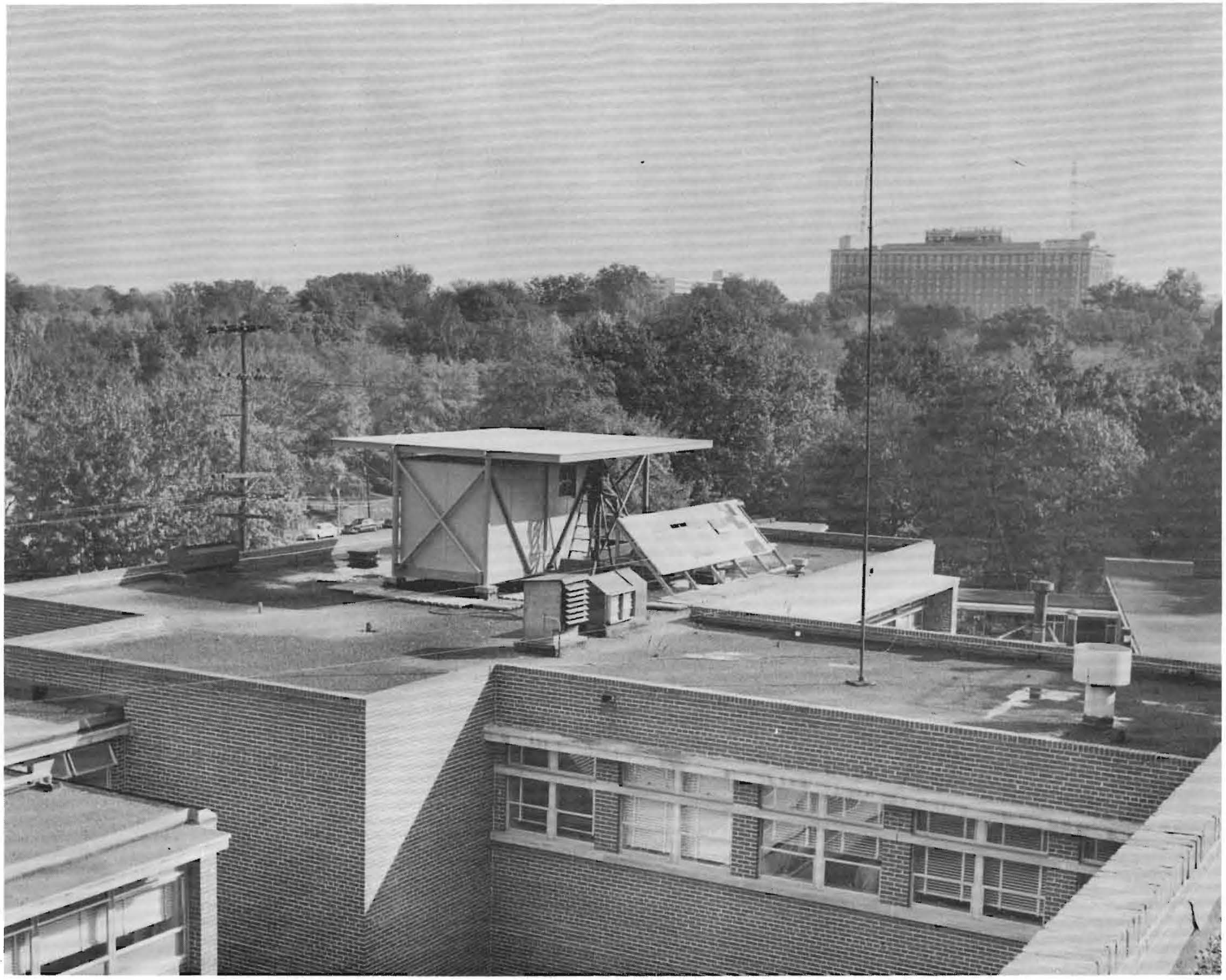

Figure 3. Antenna Ground Plane Under Construction.

arc over the center line of the plane. Future plans call for an automatic pattern recorder to be used with this pattern measuring equipment.

A preliminary cost estimate for construction of the facility is as follows:

Materials and Supplies	$ 5,764.00
Labor, including engineering and drafting	4,150.00
Total	$ 9,914.00

Detailed drawings and specifications have been prepared and are available at the Georgia Tech Engineering Experiment Station.

Respectfully submitted:

William B. Wrigley
Project Director

Approved by:

J. E. Boyd, Associate Director
Engineering Experiment Station